Year to year trends of some biological parameters of Antarctic minke whales from the view point of population monitoring

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ABSTRACT

The present study examines year to year trends of biological parameters of the Antarctic minke whales such as apparent pregnancy rate, mean age and mean body length at first ovulation, mean body length of mature animals and mean body length of animals 25 years and older from the view point of population monitoring. We used biological data of sexually or physically mature animals obtained through JARPA surveys in 1987/88 to 1999/2000 (3,478 individuals) as well as data from commercial whaling expeditions in Areas IV and V in 1971/72 to 1986/87 (26,326 individuals). Through examinations on yearly trend of such biological parameters incorporating linear regression of the value on the year, no significant trends are detected in most of the parameters (apparent pregnancy rate in both Areas, mean age at first ovulation in Area V, mean body length at the first ovulation in both Areas, mean body length of males 25 years and older in Area IV under the commercial whaling period and apparent pregnancy rate in both Areas, mean age and mean body length at the first ovulation in both Areas, mean body length of mature males in Area V, mean body length of mature females in both Areas, mean body length of animals 25 years and older in both Areas under the JARPA period) though some significant increase (mean body length of mature animals in both Areas, mean body length of males 25 years and older in Area V, mean body length of males 25 years and older in both Areas under the commercial whaling period, mean body length of mature males in Area IV under the JARPA period) or decrease (mean age at first ovulation in Area IV under the commercial whaling period) are noted. Taking potential biases for each parameter in account of considerations, the present study concludes there are no positive evidences to suggest changes in population level of the Antarctic minke whales in Areas IV and V.

KEYWORDS: ANTARCTIC MINKE WHALE, BIOLOGICAL PARAMETER, TREND, JARPA

INTRODUCTION

Density dependent changes in biological parameters of cetaceans with changes in the level of populations are generally known. Several authors reported changes in biological parameters in the southern balaenopterid whales (Mackintosh, 1942; Laws, 1961; Gambell, 1973; Lockyer, 1972, 1979; Masaki, 1978, 1979; Best, 1982; Kato, 1982, 1983, 1985, 1986b, 1987; Kato and Sakuramoto, 1991). The biological parameters of balaenopterid whales have changed in accordance with decrease in their density caused by reduction of population size itself or reduction of ecological competition. It was considered that the changes of biological parameters in the Antarctic minke whale such as decline of age at sexual maturity and increase of the growth rate were caused by reduction of populations of blue and fin whales having a strong competitive relation to minke whales, which led to greater availability of food for minke whales (Masaki, 1979; Best, 1982; Kato, 1983, 1986b, 1987, Kato and Sakuramoto, 1991). These changes in biological parameters of the Antarctic minke whales had been discussed in the IWC/SC meeting. During the JARPA review meeting in 1997, the Working Group agreed that there had been a real decline in age at sexual maturity of minke whales.

The abundance of the Antarctic minke whales was estimated as 760,000 during the IWC/SC comprehensive assessment in 1990. During 52IWC/SC meeting last year, preliminary abundance estimates using sighting data from the incomplete 3id circumpolar IWC/IDCR-SOWER surveys were discussed. In 1999, a review of the Antarctic minke whales abundance was proposed and an inter-sessional steering group was formed. During 52IWC/SC meeting the Committee recommended that an inter-sessional workshop to be held before 53IWC/SC

meeting in order to examine details of abundance estimated.

The study of biological parameters is also important with respect to both the estimation of population size and understanding of the population monitoring. For example changes in age at sexual maturity and pregnancy rate have been associated with changes in the population size of certain species. Therefore, using biological data available from past Japanese commercial whaling operations in the Antarctic for the period 1971/72-1986/87 and from the JARPA surveys for the period 1987/88-1999/00 in Areas IV and V, the present study examines year to year trends of some biological parameters such as apparent pregnancy rate, mean age and body length at the first ovulation, mean body length in mature animals and mean body length of animals 25 years and older of Antarctic minke whales from the view point of population monitoring.

MATERIALS AND METHODS

Biological data used

The present study used biological data from mature animals from past Japanese commercial whaling operations in the Antarctic and from the JARPA surveys. Data on sex, body length, foetus, number of ovulations and testis weight of whales taken in commercial whaling operations was obtained the Japanese commercial whaling database owned by the National Research Institute of Far Seas Fisheries (NRIFS). The resultant number of samples used from commercial data was 26,326 mature animals from the period 1971/72-1986/87. JARPA data was used included 3,478 animals from the period 1987/88-1999/00 in Areas IV and V (Table 1).

Sexual maturity determination

JARPA data

Sexual maturity for males was determined by examination of histological status of testis tissues. Males with seminiferous tubules over 100 μ m diameter or spermatid in the tubules were determined to be sexually mature (Kato, 1986a; Kato *et al.*, 1990, 1991). Sexual maturity for females was determined by the presence of at least one corpus luteum or albicans in both ovaries.

Japanese commercial whaling operation data

Information of sexual maturity of animals was available from the Japanese commercial whaling database owned by NRIFSF. Sexual maturity for males was determined by a testis weight. A weight of more than 0.4 kg was used as a standard criterion for maturity (Ohsumi *et al.*, 1970). Sexual maturity for females was determined by number of corpora lutea and albicantia and the number of foetus.

Age determination

JARPA data

Age of whales was determined by reading growth layers appearing on the bisected surface of the earplug. Individual age was determined using growth layers in earplug that were counted by Kato and Zenitani using a stereoscopic microscope. In addition we sometimes used the baleen plate for age determination of juvenile whales based on the method developed by Kato and Zenitani (1990).

Statistical analyses

We estimated some biological parameters by sex, catch-year and Area, and applied liner regression analyses. We set the null hypothesis H_0: the slope=0 and examined whether the slope of the regression of biological parameters on catch-year is significantly different from zero at the 5 % level.

RESULTS

Apparent pregnancy rate

Apparent pregnancy rate is defined as the proportion of pregnant females within the number of total sexually mature females. Table 2 indicates the apparent pregnancy rates by year and Area. Yearly variation in apparent pregnancy rate and the liner regression of pregnancy rate on catch-year, by Area is given in Fig. 1.
Range in apparent pregnancy rates in Area IV is 82.1-96.6% and in Area V is 77.5-98.4%. The apparent pregnancy rates maintain at high value in both Areas and periods.

In Area IV, no yearly trends of apparent pregnancy rate are seen in either the period of commercial whaling or the JARPA surveys (the null hypothesis is H_0: the slope=0, t-test of deviation of the slope of regression of pregnancy rate on catch-year from zero at the significant level of 5%, commercial: p=0.389, JARPA: p=0.651).

In Area V, apparent pregnancy rate seem to slightly increase during the period of commercial whaling but not significantly different from zero (t-test, p=0.073). On the other hands, those of during the period of the JARPA

surveys slightly degreased but the slope of the regression was not significantly different from zero (t-test, p=0.781).

Mean age at first ovulation

Mean age at first ovulation is defined as mean age of females identified by the presence of a corpus luteum and no corpus luteum in the ovaries (first ovulation). Mean age at first ovulation is given in Table 3. Fig. 2 indicates yearly variation of mean age at first ovulation and the equation of the liner regression, by Area. Mean age at first ovulation ranges 4.5-11.0 years and 5.0-11.0 years in Areas IV and V respectively.

In Area IV, mean age decreased from about 10 years during the period 1971/72-1978/79 to about 7 years during the period 1979/80-1986/87. Though mean age at first ovulation during the period after the JARPA survey started in 1987/88 slightly increased to about 8 years, yearly change and trend was not clear since the number of samples was small and different over year of sampling. A clear decreasing trend of mean age at first ovulation during the commercial whaling period could be seen and the slope of the regression was significantly different from zero (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean age on catch-year from zeroat the significant level of 5%, p=0.019). On the other hand, though mean age at first ovulation remains constant in the JARPA surveys as indicating no significant yearly trend could be seen (t-test, p=0.627).

In Area V, mean age at first ovulation with catch-year during the period of commercial whaling varied but no significant yearly trend was shown (t-test, p=0.924). Mean age at first ovulation during the period the JARPA survey (1988/89-1998/99) was slightly higher than that during the period of commercial whaling. Yearly change and trend was not clear since the number of the JARPA samples was very limited and the slope of the regression was not significantly different from zero (t-test, p=0.995).

Mean body length at the first ovulation

Mean body length at first ovulation is defined as mean body length of females having a corpus luteum of first ovulation. Table 4 indicates mean body length at the first ovulation, by catch-year and Area and Fig. 3 indicates yearly variation of mean age at first ovulation and the equation of the liner regression, by Area. Mean body length at the first ovulation ranges 8.11-8.73 m and 8.18-8.85 m in Areas IV and V, respectively.

The mean body length at the first ovulation by catch-year varied in Area IV. No significant yearly trends for either the period of commercial whaling or the JARPA surveys were shown (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean body length on catch-year from zero at the significant level of 5%, commercial: p=0.767, JARPA: p=0.403).

In Area V, mean body length at the first ovulation remains constant in the period of commercial whaling (t-test, p=0.603), while those of the JARPA period apparently increase but statistically insignificant (t-test, p=0.161).

Mean body length in mature animals

Mature males

Table 5 indicates the mean body length of mature males, by year and Area. Yearly variation of mean body length of mature males and the liner regression by Area are also given in Fig. 4. Range of mean body length in Area IV is 7.97-8.52m and in Area V is 8.16-8.62 m.

In Area IV, there is a slight increasing trend of mean body length during the period commercial whaling. On the other hand, during the period of the JARPA surveys no yearly change of mean body lengths exist. Further mean body lengths during the period of the JARPA surveys are smaller than that during the period of commercial whaling. The slopes of the regression in both the periods were significantly different from zero (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean body length on catch-year from zero at the significant level of 5%, commercial: p=0.001, JARPA: p=0.045).

In Area V, mean body length during the period of commercial whaling seems to be increased but no yearly change of during the period of the JARPA surveys is seen. Further mean body lengths during the period of the JARPA surveys are smaller than during the period of commercial whaling. For mean body length of mature animals, the slope of the regression during the period of commercial whaling is significantly different from zero (t-test, p=0.018). However, the slope of the regression was not significantly different from zero (t-test, p=0.217) during the period of the JARPA survey.

Mature females

Table 6 indicates the mean body length in mature females, by year and Area. Yearly variation of mean body length with the liner regression of mean body length on catch-year, by Area is given in Fig. 5. Ranges of estimates of mean body length are 8.62-9.05 m and 8.73-9.04 m in Areas IV and V, respectively.

In Area IV, mean body length increases with significant during the period of commercial whaling (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean body length on catch-year from zero at the significant level of 5%, p=0.0003). But during the period of the JARPA surveys no yearly change of mean body length is seen (t-test, p=0.058). The mean body lengths during the period of the JARPA surveys are slightly smaller than that of the period of commercial whaling.

Mean body length also increase during the period of commercial whaling in Area V could be seen (t-test, p=0.005) and mean body lengths in the period of the JARPA surveys are smaller than that of the period of commercial whaling and no yearly change is seen (t-test, p=0.239).

Mean body length in physically mature animals (mean body length of animals older than 24 years)

Kato (1990) considered baleen whales mostly reach asymptotic length at 25-30 years. Then, present study examine yearly trend of mean body length of physically mature animals based on mean body length of older than 24 years in this study.

Males

Table 7 indicates the mean body length in mature males, by year and Area. Fig 6 gives yearly variation of mean body length with the liner regression of mean body length on catch-year. The mean body lengths of physically mature males are 8.28-8.67 m and 8.34-8.66 m in Areas IV and V, respectively.

In Area IV, there are no yearly trends of mean body length in either the period of commercial whaling or the JARPA surveys (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean body length on catch-year from zero at the significant level of 5%, commercial: p=0.384, JARPA: p=0.140).

In Area V, the mean body length increase during the period of commercial whaling and slope of regression was significantly different from zero (t-test, p=0.005). There is no specific yearly trend of mean body length during the period of the JARPA survey for Area V (t-test, p=0.254).

Females

Table 8 indicates the mean body length in physically mature females by year and Area. Yearly variations of the mean body length by Area are given in Fig. 7. The mean body length in physically mature females ranges 8.40-9.23 m and 8.82-9.24 m in Areas IV and V, respectively.

In Area IV, the mean body length seem to be increased during the period of commercial whaling (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of mean body length on catch-year from zero at the significant level of 5%, p=0.028). But during the period of the JARPA surveys there is no yearly change mean body length is seen (t-test, p=0.267).

The increasing in mean body length during the period of commercial whaling in Area V is significant (t-test of deviation of the slope of regression of mean body length on catch-year from zero at the 5% level, p=0.002). The mean body lengths during the period of the JARPA surveys are slightly smaller than that during the period of commercial whaling, with no yearly change (t-test, p=0.370).

An additional examination of body length and age at sexual maturity of female

It has already been reported that body length and age at sexual maturity of female in Area IV using samples from commercial whaling operation in the Antarctic for the period 1971/72-1982/83 by Kato (1987). This section preliminary examined the yearly trends of body length at sexual maturity estimated by the same approaches of Kato (1992) and age at sexual maturity estimated by the approaches of Cooke (1984) using the JARPA data (Fig. 8).

Estimates of body length at sexual maturity during the period of commercial whaling are around 8.0 m, with no significantly yearly trend (the null hypothesis is H_0 : the slope=0, t-test of deviation of the slope of regression of body length on catch-year from zero at the significant level of 5%, p=0.140). In the period of the JARPA surveys, a slightly increasing trend is apparently seen but not significantly different from zero (t-test, p=0.294).

In the during commercial whaling, except for the high value of 1974/75, rage of age at sexual maturity around 6-7 years as of no significant yearly trend (t-test, p=0.601). A yearly variation and a slightly increasing trend during the period of the JARPA surveys were seen but the slope of the regression was not significantly different from zero (t-test, p=0.656).

DISCUSSION

It is well known that demographic biological parameters are under or overestimated due to sampling biases. Kato (1983,1987) and Kato and Sakuramoto (1991) clarified that the value of age at which 50% of animals attained sexual maturation was generally underestimated by biases due to the nature sexual maturity animals and large

animals are dominated in the whaling ground and also due to also catching selectivity that tended to take larger animals. And it is also clear that pregnant females dominated in the sampling area have caused overestimation of apparent pregnancy rate.

As examined by Kasamatsu and Ohsumi (1981) minke whale operation had been mostly conducted in the ice-edge zone at the Antarctic and the commercial whaling obviously tends to take larger whale lower latitudes. While the JARPA survey covers wider latitude than commercial whaling in order to neglect or minimize biases due to reproductive segregation and catching selectivity.

Furthermore the JARPA survey is designed to collected data and materials of minke whales population randomly and systematically incorporating the random sampling method, in which there is no intentional selection of the animals (Fujise *et al.*, 1997). It is expected that such difference in sampling strategy lead to potential difference in the value of estimate.

Actually, looking at given estimates of biological parameters in the present study, both estimates of age at 50% sexual mature females and body length at 50% sexual mature females by the commercial whaling data are consistently smaller than those by the JARPA survey. On the other hand, Kato (1987) indicated that the mean age and mean body length at first ovulation are potentially free from biases sue to the reproductive segregation and the catching selectivity. As a fact, the estimates of the first ovulation are relatively closer between two different sets of the samples. Length of physically mature animals (older than 24 years also) are also free from catching selectivity, because the threshold age is much older than age at full recruitment to the Antarctic whaling ground by Kato and Ohsumi (1986) and Harwood and Kato (1991). Although if the biological parameters estimated by same manner over the year the trend itself can be used even the estimates are biased (DeMaster, 1984), in order to monitor of population using the unbiased biological parameters is better. Thus, for monitoring purpose of the population these bias-free parameters are potentially superior among the parameters examined in the present study.

Table 9 summarizes statistical examination for yearly trend of each biological parameter taking account of type of sampling. As to parameters age and length at first ovulation, no specific yearly changes are detected in both commercial and the JARPA samples excepting Area IV. This suggests no specific density dependent changes may occur in early 1970s to 2000. On the other hand, significant increases exist in mean length of physically mature animals among the commercial samples while no changes among the JARPA samples. Because the length size is highly depends on nutritional condition at adolescent stage, increase of the mean length under commercial samples means increase in food availability in 1950's to 1960s. This is agreed with other independent findings of decline in age at sexual maturity by transition phase (Kato, 1987; Kato and Sakuramoto, 1991; Thomson *et al.*, 1999), which is also bias from parameters. On the other hand, no changes in the mean length under the JARPA stage means no density dependent changes or no changes in food availability for the Antarctic minke whales in 1970's to 1990's.

As above, we concluded there are no positive evidences to suggest changes in population level of the Antarctic minke whales in Areas IV and V.

It was also found that difference some trend of biological parameters between Areas IV and V.

From segregation studies using the JARPA data, the following results were clarified: 1) sex ratio and maturity rate of mike whales were related to latitude, season and school size, 2) especially older mature females were dominant the Ross Sea in Area V, 3) migration and segregation patterns of mink whales differed between Areas IV and V (Kato *et al.*, 1990, 1991; Fujise *et al.*, 1990, 1991, 1992, 1994; Fujise and Kishino, 1994; Kishino *et al.*, 1991a, 1991b). Further from the genetic studies using the JARPA data, the result obtained are consistent with the hypothesis that whales from the western part of Area IV sampled in a early period (December-first half of January) in 1989/90 and 1991/92 JARPA surveys belong to different stock than those from another sectors and period of Areas IV and V (Pastene *et al.*, 1996). These may be possible reasons of the difference in trend of some biological parameters. Therefore further examination of biological parameters is necessary to take above information into consideration sufficiently.

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Table 1. Number of mature minke whales available from past Japanese commercial whaling operations for the period 1971/72-1986/87 and from the JARPA surveys for the period 1987/88-1999/00, by Area and catch-year used in the present study.

		Area IV			Area V		
	Catch-year	Male	Female	Total	Male	Female	Total
Commercial whaling operation	71/72	882	1,496	2,378	-	-	-
	72/73	894	612	1,506	-	-	-
	73/74	692	934	1,626	-	-	-
	74/75	416	281	697	183	261	444
	75/76	188	180	368	249	103	352
	76/77	488	325	813	506	413	919
	77/78	122	295	417	319	280	599
	78/79	366	440	806	64	75	139
	79/80	999	385	1,384	375	95	470
	80/81	507	560	1,067	132	436	568
	81/82	539	908	1,447	368	715	1,083
	82/83	498	424	922	394	1,347	1,741
	83/84	554	443	997	415	871	1,286
	84/85	131	340	471	326	542	868
	85/86	221	284	505	330	637	967
	86/87	190	305	495	160	831	991
JARPA survey	87/88 **	120	59 (119)*	179	-	-	-
	88/89**	-	-	-	70	107	177
	89/90	160	85 (142)*	245	-	-	-
	90/91	-	-	-	148	131	279
	91/92	135	84 (123)*	219	-	-	-
	92/93	-	-	-	155	123	278
	93/94	158	69 (130)*	227	-	-	-
	94/95	-	-	-	170	87	257
	95/96	170	76 (126)*	246	-	-	-
	96/97	-	-	-	107	166	273
	97/98	147	28 (123)*	175	-	-	-
	98/99	-	-	-	181	80	261
	99/00	140	101 (160)*	241	-	-	-

* : included of immature animals

**: feasibility study

Table 2. Apparent pregnancy rates of minke whales in past Japanese commercial whaling operations and the JARPA surveys, by Area and catch-year.

		Area IV			Area V		
		Number of females		Apparent pregnancy	Number of females		Apparent pregnancy
	Catch-year	Mature	Pregnant	rate (%)	Mature	Pregnant	rate (%)
Commercial whaling operation	71/72	1,496	1,396	93.3	-	-	-
	72/73	612	540	88.2	-	-	-
	73/74	934	819	87.7	-	-	-
	74/75	281	231	82.2	261	237	90.8
	75/76	180	161	89.4	103	92	89.3
	76/77	325	294	90.5	413	350	84.7
	77/78	295	244	82.7	280	217	77.5
	78/79	440	386	87.7	75	70	93.3
	79/80	385	349	90.6	95	89	93.7
	80/81	560	500	89.3	436	384	88.1
	81/82	908	835	92.0	715	645	90.2
	82/83	424	348	82.1	1,347	1,226	91.0
	83/84	443	412	93.0	871	812	93.2
	84/85	340	316	92.9	542	511	94.3
	85/86	284	269	94.7	637	590	92.6
	86/87	305	267	87.5	831	781	94.0
JARPA survey	87/88 *	59	57	96.6	-	-	-
	88/89*	-	-	-	107	99	92.5
	89/90	85	80	94.1	-	-	-
	90/91	-	-	-	131	108	82.4
	91/92	84	72	85.7	-	-	-
	92/93	-	-	-	123	121	98.4
	93/94	69	62	89.9	-	-	-
	94/95	-	-	-	87	68	78.2
	95/96	76	68	89.5	-	-	-
	96/97	-	-	-	166	144	86.7
	97/98	28	25	89.3	-	-	-
	98/99	-	-	-	80	72	90.0
	99/00	101	96	95.0	-	-	-

* : feasibility study

Table 3. Mean age of females minke whales at the first ovulation, by Area.

		Mean age (years)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	9.7	4.4	4	22	31	-	-	-	-	-
	72/73	9.2	5.0	6	22	9	-	-	-	-	-
	73/74	6.3	3.2	4	11	4	-	-	-	-	-
	74/75	11.0	3.4	7	15	4	7.3	1.2	6	8	3
	75/76	10.5	4.9	7	14	2	8.5	4.4	4	17	8
	76/77	10.8	5.6	5	18	4	6.6	2.3	3	9	5
	77/78	7.0	5.7	3	11	2					0
	78/79	10.5	3.3	6	17	8	10.0		10	10	1
	79/80	7.1	2.5	4	13	11	6.0	2.7	2	9	5
	80/81	6.5	2.4	1	12	21	8.4	2.5	6	14	9
	81/82	7.6	2.7	4	13	23	8.6	2.5	5	12	12
	82/83	7.4	2.3	5	11	5	10.8	3.6	5	15	8
	83/84	6.9	3.0	3	19	26	6.9	2.9	2	18	43
	84/85	6.9	2.9	3	14	11	7.3	3.8	2	16	12
	85/86	4.5	0.7	4	5	2	5.0	2.8	1	10	7
	86/87	8.0		8	8	1	9.3	5.8	3	17	4
JARPA survey	87/88 *	8.9	2.1	6	11	7	-	-	-	-	-
	88/89*	-	-	-	-	-	8.0		8	8	1
	89/90	5.3	1.2	4	8	9	-	-	-	-	-
	90/91	-	-	-	-	-	11.0		11	11	1
	91/92	7.0	0.0	7	7	3	-	-	-	-	-
	92/93	-	-	-	-	-	9.2	1.1	8	10	5
	93/94	8.0	1.9	6	11	5	-	-	-	-	-
	94/95	-	-	-	-	-	8.0		8	8	1
	95/96	10.0		10	10	1	-	-	-	-	-
	96/97	-	-	-	-	-	10.3	0.6	10	11	3
	97/98					0	-	-	-	-	-
	98/99	-	-	-	-	-	8.6	1.5	7	12	8
	99/00	7.7	1.2	7	9	3	-	-	-	-	-

* : feasibility study

Table 4. Mean body length of females minke whales at the first ovulation, by Area.

		Body length (m)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	8.33	0.36	7.6	9.4	85	-	-	-	-	-
	72/73	8.27	0.22	7.7	8.6	26	-	-	-	-	-
	73/74	8.23	0.33	7.3	8.8	35	-	-	-	-	-
	74/75	8.11	0.48	7.2	8.7	7	8.31	0.45	7.7	9.2	14
	75/76	8.40	0.17	8.2	8.7	7	8.33	0.29	7.9	8.9	13
	76/77	8.14	0.27	7.6	8.6	12	8.20	0.31	7.5	8.7	17
	77/78	8.73	0.38	8.2	9.0	4	8.85	0.21	8.7	9	2
	78/79	8.37	0.44	7.7	9.1	11					0
	79/80	8.51	0.40	7.7	9.3	15	8.44	0.35	8.1	9.2	11
	80/81	8.45	0.34	7.8	9.3	25	8.50	0.23	8.1	8.8	11
	81/82	8.24	0.29	7.5	8.8	26	8.43	0.30	8.1	9	17
	82/83	8.46	0.32	8.0	8.8	5	8.37	0.24	8.0	8.7	11
	83/84	8.44	0.36	7.7	9.2	34	8.35	0.41	7.5	9.6	49
	84/85	8.34	0.32	7.8	8.9	14	8.33	0.35	7.7	9.0	15
	85/86	8.23	0.28	7.9	8.5	4	8.51	0.20	8.2	8.7	7
	86/87	8.20		8.2	8.2	1	8.54	0.23	8.2	8.7	5
JARPA survey	87/88 *	8.28	0.36	8.0	9.0	7	-	-	-	-	-
	88/89*	-	-	-	-	-	8.27		8.3	8.3	1
	89/90	8.36	0.27	7.9	8.8	10	-	-	-	-	-
	90/91	-	-	-	-	-	8.18		8.2	8.2	1
	91/92	8.37	0.44	7.9	8.8	4	-	-	-	-	-
	92/93	-	-	-	-	-	8.31	0.34	7.8	8.7	5
	93/94	8.58	0.21	8.3	9.0	8	-	-	-	-	-
	94/95	-	-	-	-	-	8.83		8.8	8.8	1
	95/96	8.63		8.6	8.6	1	-	-	-	-	-
	96/97	-	-	-	-	-	8.62	0.31	8.3	8.9	3
	97/98	8.56		8.6	8.6	1	-	-	-	-	-
	98/99	-	-	-	-	-	8.50	0.40	8.0	9.3	8
	99/00	8.30	0.11	8.2	8.4	3	-	-	-	-	-

* : feasibility study

Table 5. Mean body length in mature males, by Area.

		Mean body length (m)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	8.34	0.38	6.7	9.6	882	-	-	-	-	-
	72/73	8.23	0.43	6.3	9.5	894	-	-	-	-	-
	73/74	8.16	0.43	6.7	9.3	692	-	-	-	-	-
	74/75	7.97	0.54	6.0	9.4	416	8.35	0.44	7.1	10.6	183
	75/76	8.23	0.48	6.9	9.6	188	8.38	0.42	7.3	9.7	249
	76/77	8.24	0.45	6.5	9.5	488	8.27	0.43	6.8	9.6	506
	77/78	8.34	0.47	7.2	9.2	122	8.32	0.42	6.6	9.2	319
	78/79	8.24	0.38	7.4	9.3	366	8.16	0.41	7.2	9.1	64
	79/80	8.43	0.42	7.0	9.6	999	8.33	0.42	7.1	9.5	375
	80/81	8.33	0.39	6.8	9.4	507	8.30	0.37	7.1	9.2	132
	81/82	8.38	0.36	7.1	9.6	539	8.39	0.35	7.3	9.6	368
	82/83	8.43	0.37	7.2	9.9	498	8.42	0.33	7.5	9.3	394
	83/84	8.34	0.39	7.1	9.6	554	8.31	0.42	6.8	9.5	415
	84/85	8.38	0.31	7.4	9.1	131	8.43	0.35	7.4	9.7	326
	85/86	8.52	0.34	7.1	9.3	221	8.48	0.34	7.2	9.8	330
	86/87	8.52	0.34	7.2	9.2	190	8.62	0.34	7.5	9.4	160
JARPA survey	87/88 *	8.38	0.39	7.3	9.3	120	-	-	-	-	-
	88/89*	-	-	-	-	-	8.19	0.43	7.1	9.1	70
	89/90	8.36	0.38	7.3	9.4	160	-	-	-	-	-
	90/91	-	-	-	-	-	8.35	0.40	6.6	9.2	148
	91/92	8.37	0.39	6.7	9.2	135	-	-	-	-	-
	92/93	-	-	-	-	-	8.37	0.38	7.2	9.6	155
	93/94	8.37	0.41	7.1	9.3	158	-	-	-	-	-
	94/95	-	-	-	-	-	8.30	0.41	7.0	9.2	170
	95/96	8.37	0.40	7.0	9.2	170	-	-	-	-	-
	96/97	-	-	-	-	-	8.30	0.33	7.6	9.4	107
	97/98	8.44	0.39	7.0	9.5	147	-	-	-	-	-
	98/99	-	-	-	-	-	8.39	0.41	7.1	9.6	178
	99/00	8.46	0.43	7.1	9.5	140	-	-	-	-	-

* : feasibility study

Table 6. Mean body length in mature females, by Area.

		Mean body length (m)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	8.78	0.41	7.3	10.0	1,496	-	-	-	-	-
	72/73	8.76	0.42	7.7	10.0	612	-	-	-	-	-
	73/74	8.70	0.41	7.0	9.9	934	-	-	-	-	-
	74/75	8.62	0.41	7.2	9.9	281	8.88	0.43	7.4	10.0	261
	75/76	8.82	0.44	7.5	10.2	180	8.82	0.40	7.9	10.0	103
	76/77	8.68	0.46	7.2	10.1	325	8.77	0.43	7.3	10.0	413
	77/78	8.88	0.43	8.0	10.3	295	8.82	0.42	7.8	9.8	280
	78/79	8.76	0.41	7.5	10.1	440	8.77	0.46	7.8	9.7	75
	79/80	8.86	0.38	7.7	10.0	385	8.81	0.41	8.0	9.9	95
	80/81	8.91	0.37	7.8	10.0	560	8.82	0.37	7.7	10.1	436
	81/82	8.88	0.41	7.5	10.6	908	8.84	0.39	7.9	10.1	715
	82/83	8.95	0.38	7.6	10.0	424	8.92	0.37	7.8	10.2	1,347
	83/84	8.82	0.41	7.0	10.1	443	8.84	0.40	7.5	9.9	871
	84/85	8.89	0.38	7.8	10.2	340	8.91	0.38	7.7	10.0	542
	85/86	9.01	0.35	7.9	9.9	284	8.99	0.35	7.8	10.0	637
	86/87	9.05	0.37	7.9	10.3	305	9.04	0.35	7.9	10.2	831
JARPA survey	87/88 *	8.90	0.45	8.0	9.9	59	-	-	-	-	-
	88/89*	-	-	-	-	-	8.78	0.39	7.6	9.7	107
	89/90	8.92	0.48	7.9	10.1	85	-	-	-	-	-
	90/91	-	-	-	-	-	8.83	0.39	8.0	9.8	131
	91/92	8.91	0.39	7.9	9.8	84	-	-	-	-	-
	92/93	-	-	-	-	-	8.82	0.38	7.8	9.7	123
	93/94	8.99	0.41	8.1	9.8	69	-	-	-	-	-
	94/95	-	-	-	-	-	8.73	0.40	7.7	9.7	87
	95/96	8.93	0.35	8.1	9.9	76	-	-	-	-	-
	96/97	-	-	-	-	-	8.85	0.38	7.9	10.1	166
	97/98	8.97	0.40	8.2	9.8	28	-	-	-	-	-
	98/99	-	-	-	-	-	8.95	0.44	8.0	10.1	80
	99/00	8.98	0.39	8.1	9.9	101	-	-	-	-	-

* : feasibility study

Table 7. Mean body length of males older than 24 years, by Area.

		Mean body length (m)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	8.47	0.31	7.9	9.1	42	-	-	-	-	-
	72/73	8.53	0.37	7.9	9.5	36	-	-	-	-	-
	73/74	8.43	0.36	7.5	9.2	40	-	-	-	-	-
	74/75	8.28	0.34	7.7	9.4	35	8.43	0.21	8.2	8.6	3
	75/76					0	8.45	0.45	7.9	9.6	13
	76/77	8.31	0.44	7.5	9.2	12	8.36	0.42	6.7	9.2	45
	77/78	8.67	0.23	8.5	9.1	6	8.44	0.33	7.9	9.1	25
	78/79	8.38	0.36	7.8	9.3	30	8.37	0.33	7.8	8.7	6
	79/80	8.57	0.35	7.8	9.4	134	8.56	0.35	7.7	9.2	27
	80/81	8.48	0.30	7.9	9.0	49	8.51	0.27	8.1	9.0	20
	81/82	8.41	0.29	7.9	9.3	55	8.49	0.35	7.7	9.3	48
	82/83	8.61	0.37	7.9	9.9	60	8.47	0.31	8.0	9.3	41
	83/84	8.48	0.36	7.4	9.2	37	8.45	0.39	7.8	9.3	25
	84/85	8.42	0.30	8.0	9.0	21	8.50	0.34	7.9	9.1	35
	85/86	8.51	0.35	8.0	9.3	44	8.63	0.29	8.1	9.8	48
	86/87	8.53	0.30	8.0	9.2	36	8.66	0.33	7.9	9.3	40
JARPA survey	87/88 *	8.49	0.33	7.8	9.3	25	-	-	-	-	-
	88/89*	-	-	-	-	-	8.34	0.39	7.8	8.8	11
	89/90	8.57	0.34	7.9	9.4	33	-	-	-	-	-
	90/91	-	-	-	-	-	8.51	0.34	7.8	9.1	35
	91/92	8.48	0.32	7.8	9.2	36	-	-	-	-	-
	92/93	-	-	-	-	-	8.50	0.35	7.7	9.6	56
	93/94	8.57	0.27	8.1	9.1	32	-	-	-	-	-
	94/95	-	-	-	-	-	8.47	0.41	7.6	9.1	38
	95/96	8.53	0.31	7.9	9.2	49	-	-	-	-	-
	96/97	-	-	-	-	-	8.47	0.31	8.0	9.4	33
	97/98	8.55	0.29	7.8	9.2	52	-	-	-	-	-
	98/99	-	-	-	-	-	8.51	0.30	7.8	9.2	60
	99/00	8.62	0.31	7.9	9.3	39	-	-	-	-	-

* : feasibility study

Table 8. Mean body length of females older than 24 years, by Area.

		Mean body length (m)									
		Area IV					Area V				
	Catch-year	Mean	S.D.	Min.	Max.	N	Mean	S.D.	Min.	Max.	N
Commercial whaling operation	71/72	8.92	0.38	8.0	9.9	91	-	-	-	-	-
	72/73	8.99	0.31	8.2	9.6	26	-	-	-	-	-
	73/74	8.90	0.38	7.9	9.9	63	-	-	-	-	-
	74/75	8.55	0.38	7.2	9.0	30	8.94	0.49	8.1	9.6	10
	75/76	8.97	0.30	8.4	9.4	22	9.00	0.30	8.7	9.3	3
	76/77	8.40	0.67	7.2	9.2	6	8.82	0.53	7.2	9.6	33
	77/78	8.90	0.34	8.2	9.5	31	9.01	0.33	8.5	9.7	22
	78/79	8.83	0.40	8.0	10.0	43	8.92	0.51	7.9	9.7	13
	79/80	8.99	0.40	7.9	10.0	74	8.95	0.38	8.1	9.7	17
	80/81	9.06	0.36	8.2	9.9	99	9.00	0.38	8.2	10.1	103
	81/82	9.03	0.40	8.0	10.2	155	8.97	0.36	8.0	9.8	132
	82/83	9.02	0.37	8.1	9.8	59	9.07	0.37	8.0	10.1	171
	83/84	9.06	0.39	8.0	9.9	31	9.10	0.31	8.5	9.8	77
	84/85	9.02	0.34	8.1	9.8	52	9.06	0.33	8.3	9.9	74
	85/86	9.10	0.32	8.3	9.8	47	9.08	0.31	8.3	9.9	148
	86/87	9.20	0.33	8.4	10.3	64	9.14	0.35	8.2	10.2	200
JARPA survey	87/88 *	9.07	0.51	8.4	9.9	7	-	-	-	-	-
	88/89*	-	-	-	-	-	9.02	0.43	8.2	9.7	11
	89/90	9.19	0.49	8.4	10.1	15	-	-	-	-	-
	90/91	-	-	-	-	-	9.02	0.34	8.4	9.8	31
	91/92	9.10	0.36	8.3	9.8	21	-	-	-	-	-
	92/93	-	-	-	-	-	9.05	0.33	8.2	9.7	41
	93/94	9.20	0.34	8.4	9.8	14	-	-	-	-	-
	94/95	-	-	-	-	-	8.96	0.33	8.3	9.7	24
	95/96	9.12	0.36	8.3	9.9	31	-	-	-	-	-
	96/97	-	-	-	-	-	8.97	0.36	8.1	10.0	75
	97/98	9.23	0.29	8.9	9.8	7	-	-	-	-	-
	98/99	-	-	-	-	-	9.24	0.35	8.3	10.1	29
	99/00	9.16	0.36	8.4	9.9	36	-	-	-	-	-

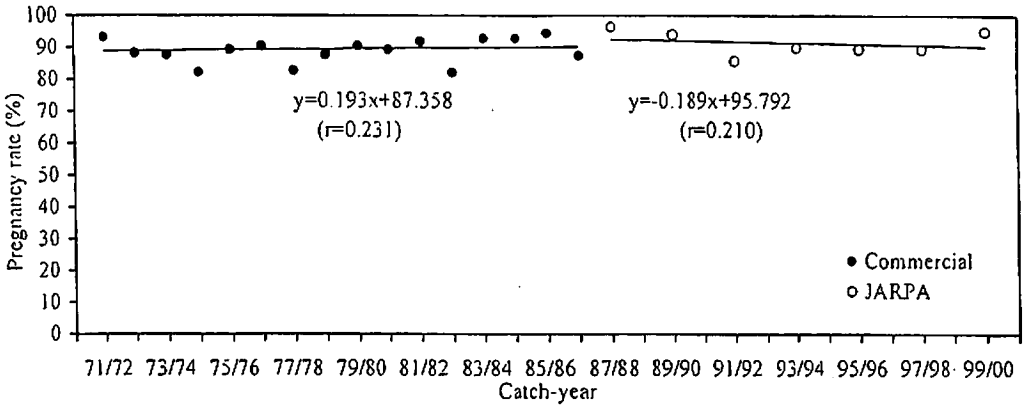
* : feasibility study

Table 9. Summary of statistical examination for several biological parameters of the Antarctic minke whales.
The null hypothesis is H0: the slope=0, and t-test for deviation of the slope of the regression from zero at the significant level of 5 % used.
Parentheses indicated probability using t-test. Constant: not significant, increase: significant increase, decrease: significant decrease.

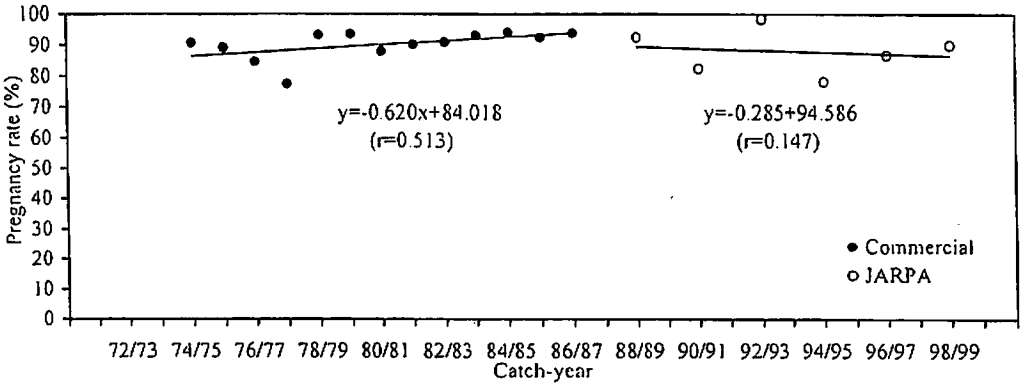
		Commercial		JARPA	
		Area IV	Area V	Area IV	Area V
Free form bias by catching selectivity and reproductive segregation					
Mean age at first ovulation		**decrease**	constant	constant	constant
		(0.019)	(0.924)	(0.627)	(0.995)
Mean body length at first ovulation		constant	constant	constant	constant
		(0.767)	(0.603)	(0.403)	(0.161)
Mean body length of animals older than 24 years	Male	constant	**increase**	constant	constant
		(0.384)	**(0.005)**	(0.140)	(0.254)
	Female	**increase**	**increase**	constant	constant
		(0.028)	**(0.002)**	(0.267)	(0.370)
Biases by catching selectivity and reproductive segregation					
Apparent pregnancy rate		constant	constant	constant	constant
		(0.389)	(0.073)	(0.651)	(0.781)
Mean body length of mature animals	Male	**increase**	**increase**	**increase**	constant
		(0.001)	**(0.018)**	**(0.045)**	(0.217)
	Female	**increase**	**increase**	constant	constant
		(0.0003)	**(0.005)**	**(0.058)**	(0.239)
Age at 50% sexual mature*	Female	constant	-	constant	-
		(0.601)		(0.656)	
Body length at 50 % sexual mature**	Female	constant	-	constant	-
		(0.140)		(0.294)	

* : According the approaches of Cooke (1984)
** : According the approaches of Kato (1992)

Area IV



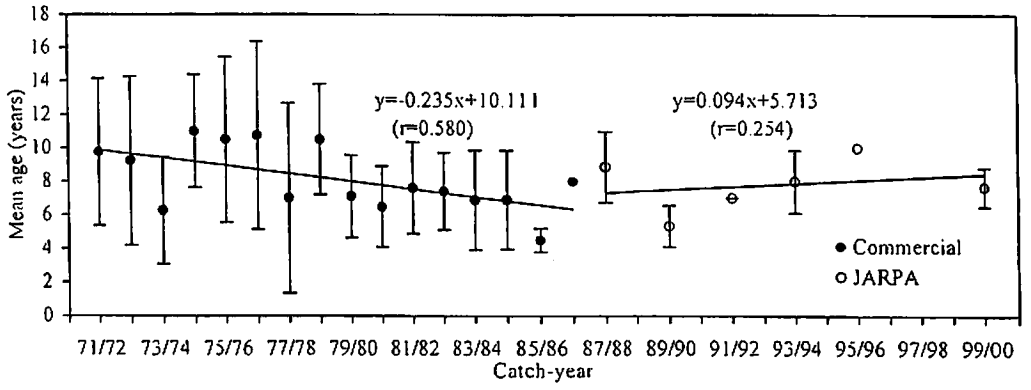
Area V



87/88-88/89 : feasibility study

Fig. 1. Yearly variation in apparent pregnancy rate, by Area.

Area IV



Area V

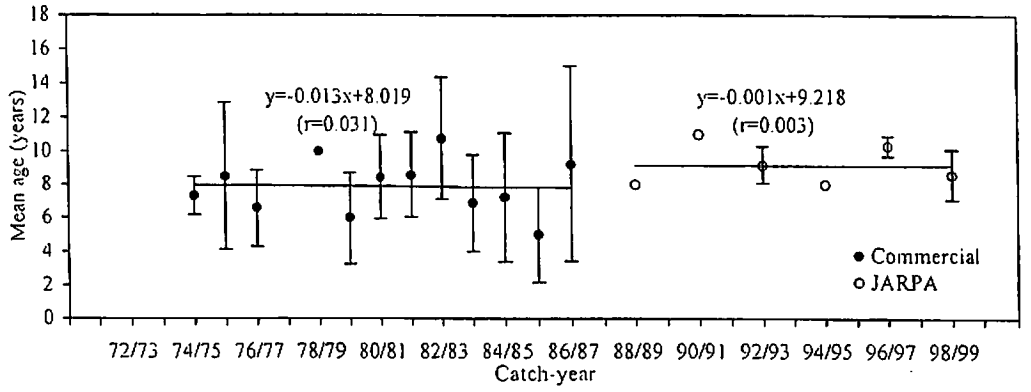


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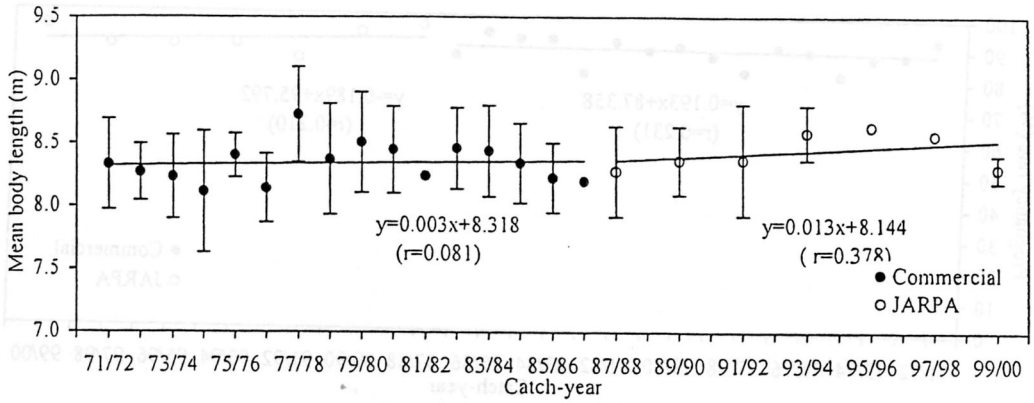
Fig. 2. Yearly variation of mean±S.D. age of females at the first ovulation, by Area.

Area IV



Area V

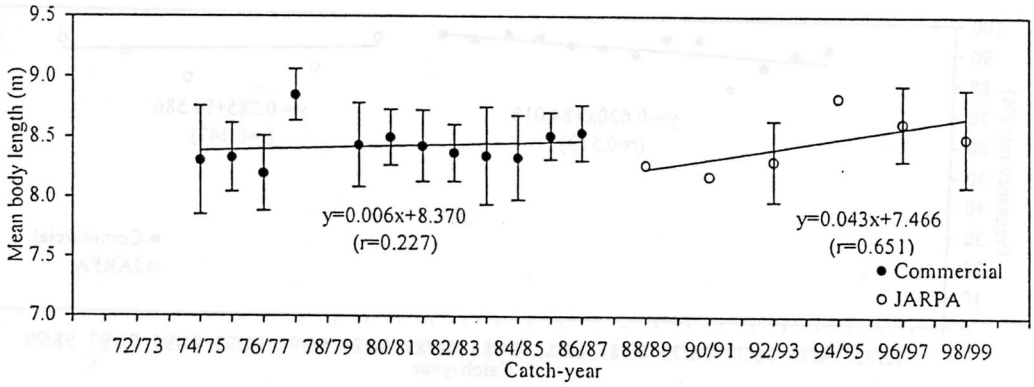


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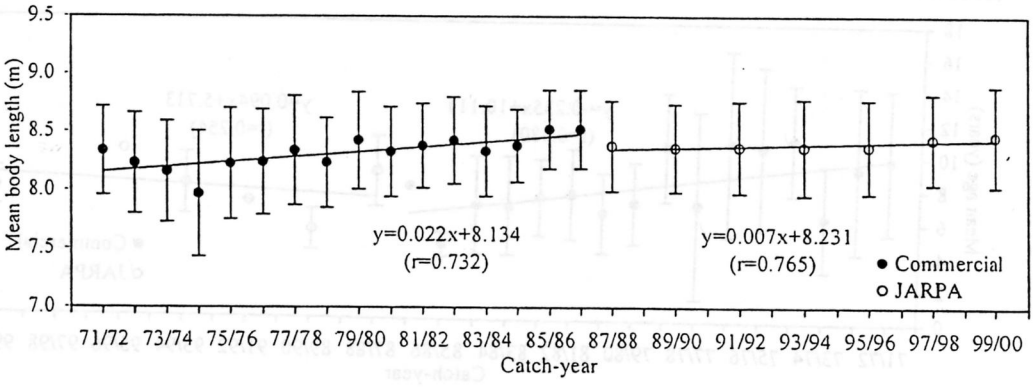
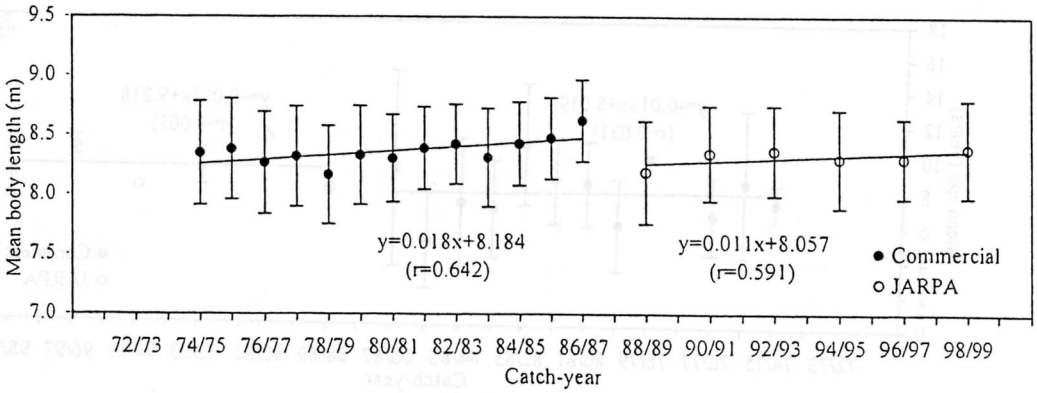
Fig. 3. Yearly variation of mean± S.D. body length of females at the first ovulation, by Area.

Area IV



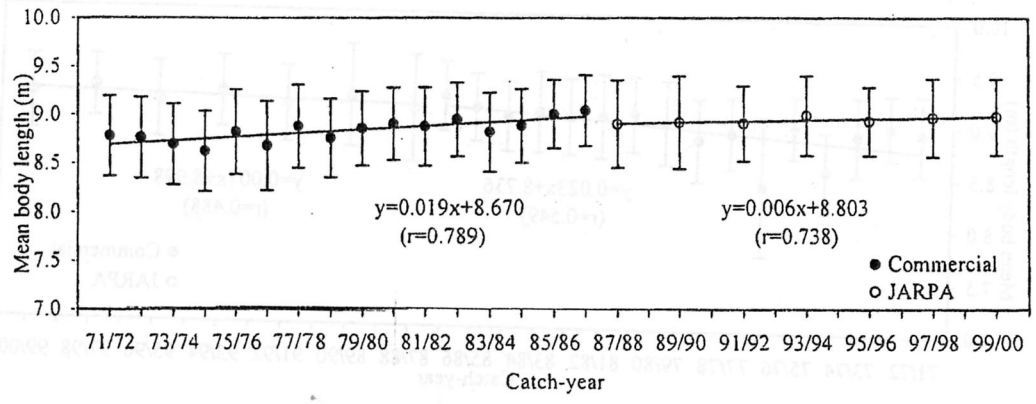
Area V



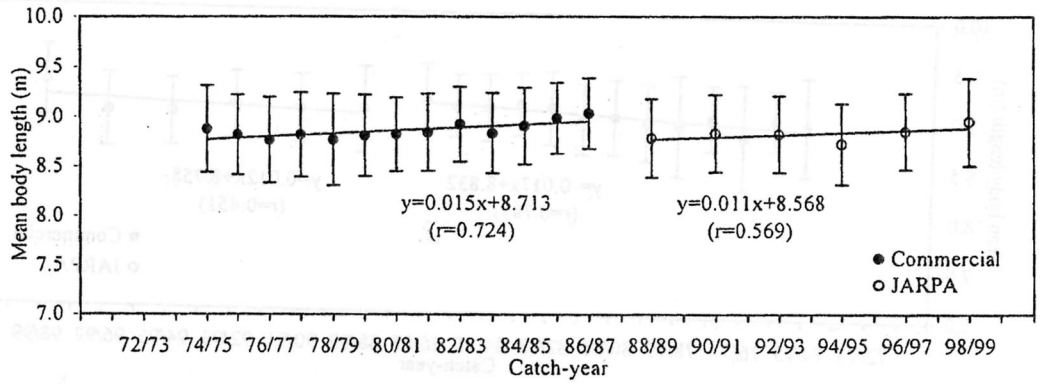
87/88-88/89 : feasibility study

Fig. 4. Yearly variation of mean± S.D. body length of mature males, by Area.

Area IV



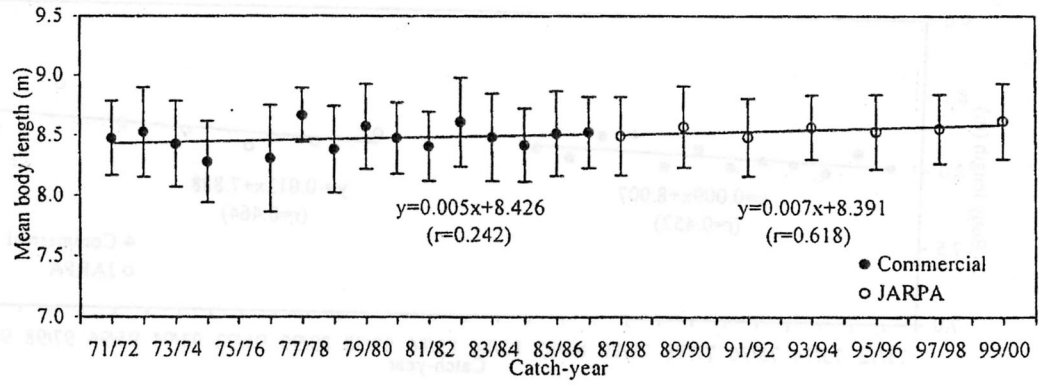
Area V



87/88-88/89 : feasibility study

Fig. 5. Yearly variation of mean±S.D. body length of mature females, by Area.

Area IV



Area V

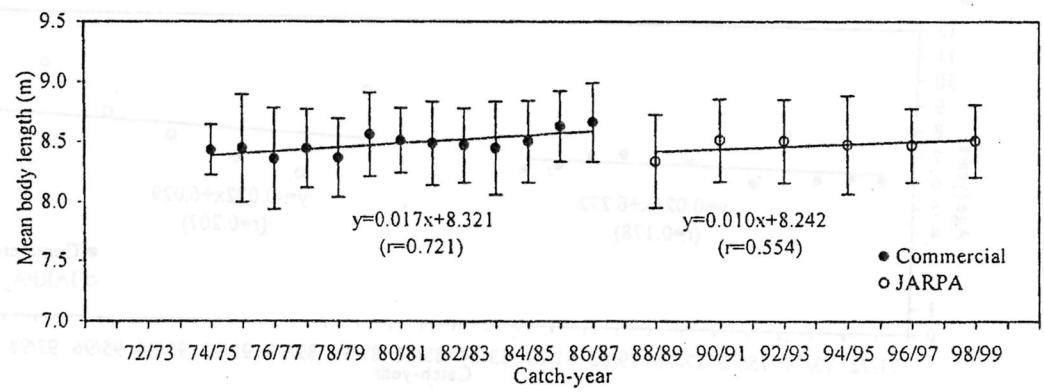


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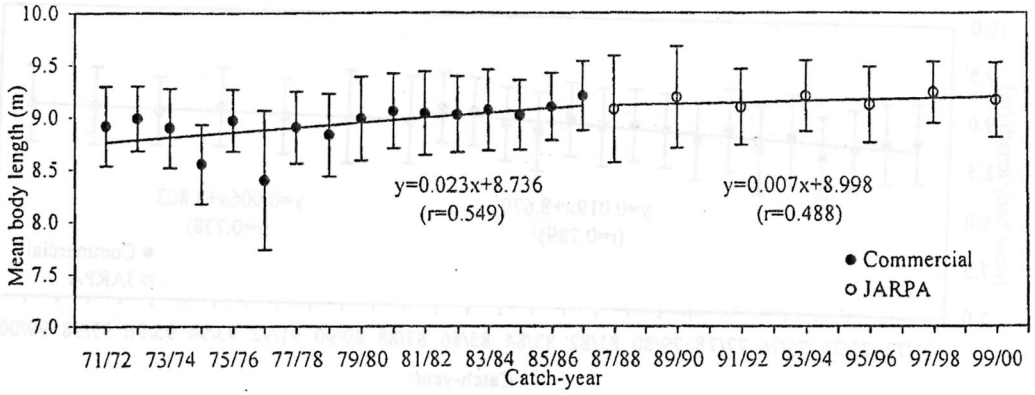
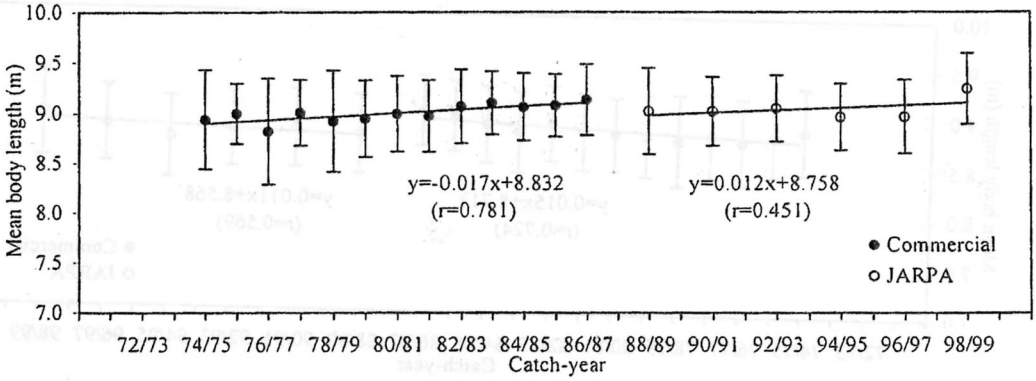
Fig. 6. Yearly variation of mean±S.D. body length of males older than 24 years, by Area.

Area IV



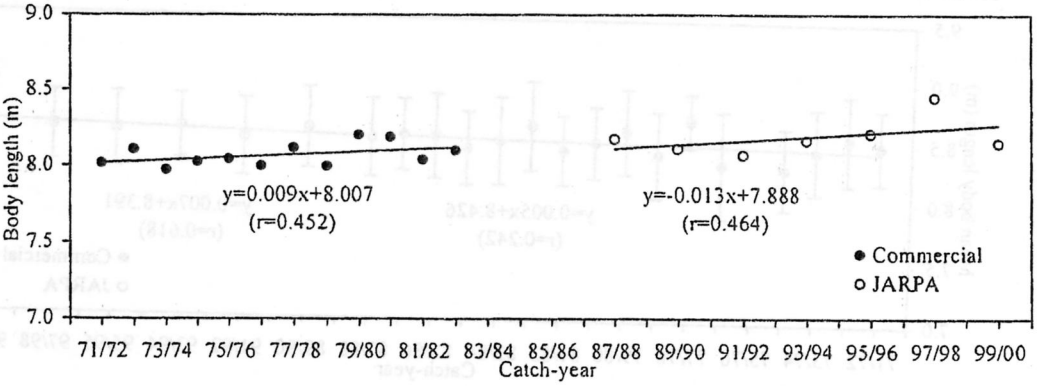
Area V



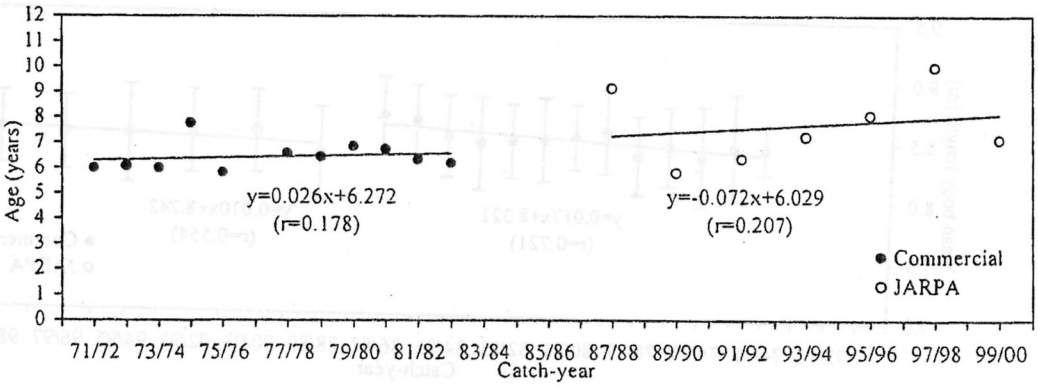
87/88-88/89 : feasibility study

Fig. 7. Yearly variation of mean±S.D. body length of females older than 24 years, by Area.

Body length



Age



87/88 : feasibility study

Fig. 8. Yearly variation in body length and age at sexual maturityof female in Area IV. 1971/72-1982/83 data are form Kato (1987).